NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION

Experimental Study ND 2002-01

Base Reinforcement Using Geogrid

Construction Report

NH-4-52(044)058

April 2004

Prepared by

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

BISMARCK, NORTH DAKOTA
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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

EXPERIMENTAL PROJECT REPORT

EXPERIMENTAL PROJECT	EXPERIMENTAL PROJECT NO. 1 — STATE: ND; YEAR: 2002 - NUMBER: 01; SURF:	CONSTRUCTION PROJ NO: NH-4-052(044)058; LOCATION: Ward & Renville Co.
	EVALUATION FUNDING 48: 1 x HP&R; 2 x CONSTRUCTION; 3 DEMONSTRATION; 4 IMPLEMENTATION	NEEP NO. 49; PROPRIETARY FEATURE? 51: x Yes; No
SHORT TITLE	TITLE 52: Base Reinforcement Using Geogrid	
THIS FORM	DATE 140: MO. 04 -- YR. 04	REPORTING: 1 x INITIAL; 2 ANNUAL; 3 FINAL
KEY WORDS	KEY WORD 1: Base Reinforcement	KEY WORD 2: Geogrid
	KEY WORD 3:	KEY WORD 4:
	UNIQUE WORD 233:	PROPRIETARY FEATURE NAME: TENSAR

CHRONOLOGY	Date Work Plan Approved	Date Feature Constructed	Evaluation Scheduled Until	Evaluation Extended Until	Date Evaluation Terminated
	277	281: 7-03	285: 2013	289	293

QUANTITY AND COST	QUANTITY OF UNITS (ROUNDED TO WHOLE NUMBERS)	UNITS	UNIT COST (*Dollars, Cents*)
	297: 25,031	305: 1 LIN. FT; 2 x SY; 3 SY-IN; 4 CY; 5 TON; 6 LBS; 7 EACH; 8 LUMP SUM	306: $2.78

AVAILABLE EVALUATION REPORTS	CONSTRUCTION	PERFORMANCE	FINAL
	315: x		

EVALUATION	CONSTRUCTION PROBLEMS	PERFORMANCE
	318: 1 NONE; 2 x SLIGHT; 3 MODERATE; 4 SIGNIFICANT; 5 SEVERE	319: 1 EXCELLENT; 2 GOOD; 3 SATISFACTORY; 4 MARGINAL; 5 UNSATISFACTORY

APPLICATION		
320	1 ADOPTED AS PRIMARY STD.; 2 PERMITTED ALTERNATIVE; 3 ADOPTED CONDITIONALLY	4 PENDING; 5 REJECTED; 6 NOT CONSTRUCTED — *(Explain in remarks if 3, 4, 5, or 6 is checked)*

REMARKS

321 Belly-dump trucks placing base material on the geogrid can cause waves in the material if it is dumped too fast. This can also happen during the spreading of the base if it is spread too fast. Placing small piles of base material on geogrid seams and on small waves that develop can help hold it down while the base material in the windrow is being spread.

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Written by
Mike Marquart

Disclaimer

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Purpose and Need

North Dakota's aging highways are being rehabilitated with thicker base sections to improve pavement performance. The bases are being constructed with virgin aggregates and blends of recycled materials to provide adequate drainage and support for the pavement. Most of the aggregate used is a local material that is being depleted and is becoming harder to find. In some areas, aggregate is being brought in from surrounding states, which adds substantial costs to rebuilding the roadway.

The North Dakota Department of Transportation (NDDOT) is looking at ways to improve the performance of the pavement, decrease future maintenance costs, conserve aggregate resources, and reduce the time needed to rehabilitate the roadway.

Objective

The objective of this study is to determine if using geogrid as a base reinforcement will provide the performance characteristics required, while reducing aggregate use and construction time.

Scope

The scope of the work was to install geogrid in the base material of a newly constructed roadbed to reinforce the base. The geogrid was placed 6" below the top of the base in two sections having different base thicknesses. These sections will be compared to a standard section for 10 years and will include distresses, pavement condition, maintenance costs, and FWD data.

Location

Geogrid was installed on project NH-4-052(044)058. The project is on US Highway 52 from Donnybrook to Carpio. This section of highway is northwest of Minot in Ward and Renville counties. Refer to Figure 1 on the next page for the location.

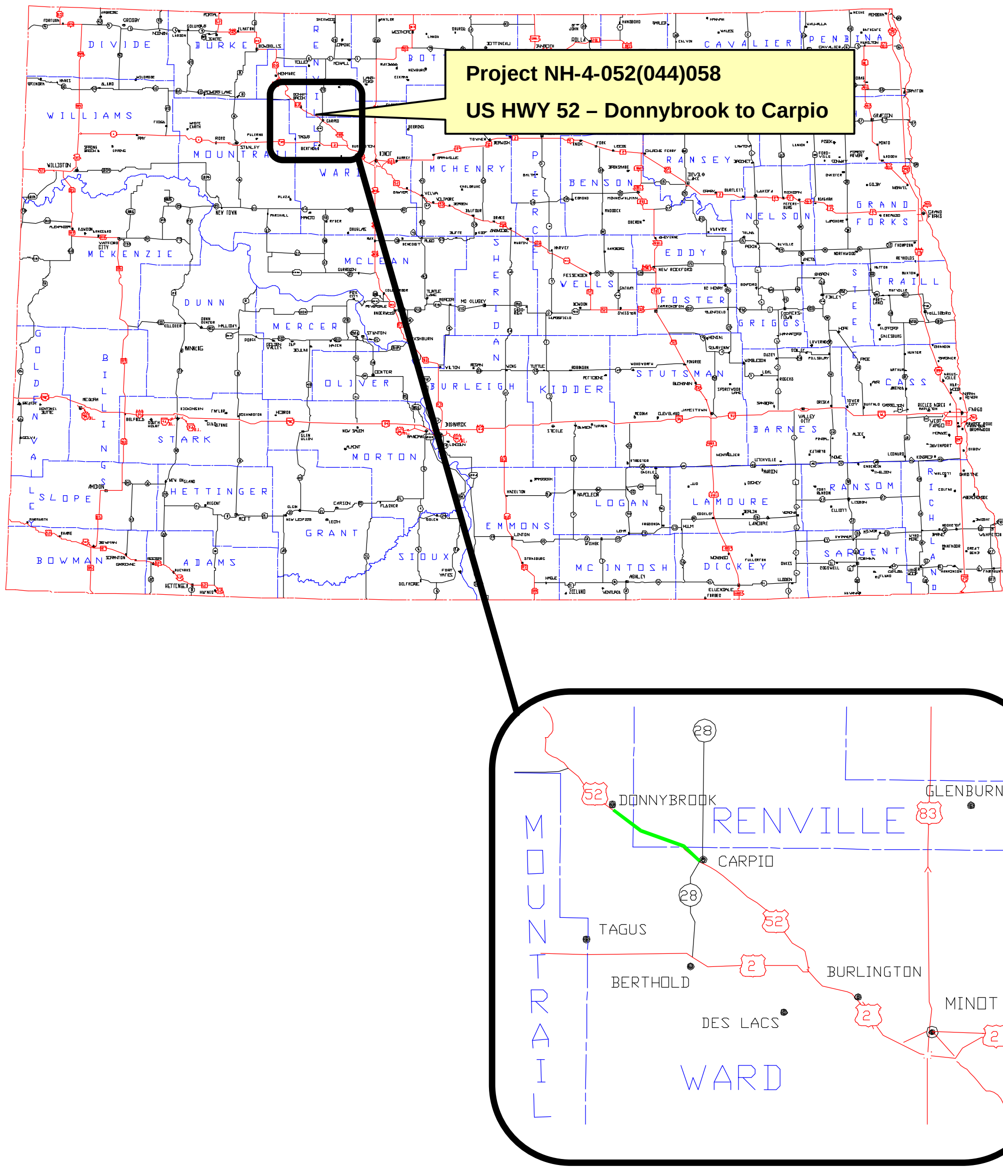


Figure 1 - Project Location.

Design

According to the manufacturer, and research conducted by the Federal Aviation Administration (FAA), and the Army Corps of Engineers (COE), utilizing geogrid in the base section has a Traffic Benefit Ratio (TBR) of 3 using Tensar BX1100.

The TBR is a multiplier of 3 placed on the design ESALs. Refer to photos 1 and 2 for a sample of the Tensar BX 1100 Geogrid. Referring to Table 1 below, Section 1 (control) has design ESALs of 1,813,132 while Section 2 (using geogrid, with normal base depth) has design ESALs of 5,439,396.

Photo 1 - Tensar BX1100 Geogrid

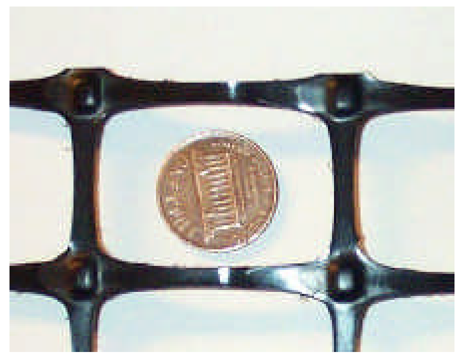


Photo 2- Size of geogrid opening vs a penny.

Section	Design ESALs	Design ESAL Calculated By
1 (Control)	1,813,132	Darwin 3.01and SpectraPave2
2	5,439,396	SpectraPave2
3	1,812,314	SpectraPave2

Table 1

The pavement thickness design for the test sections utilized DARWIN (1993 AASHTO Design Software) and SpectraPave2 (design software from Tensar, the geogrid manufacturer). Tensar recommends that the geogrid be placed 10” to 13” below the top of the asphalt surface for the best performance. Tensar indicates that by utilizing geogrid in the base, total base depth can be reduced by approximately 6” while carrying the same traffic.

Three different sections were designed based on the following parameters: 5,500 psi soil modulus; 445 two-way flexible ESALs; 1.3% growth rate; 1,841,393 accumulated one-way flexible ESALs; 80% reliability; 20-year design life; Class 31 HBP; and a blended base (consisting of approximately 50% salvaged HBP and 50% virgin aggregate). Refer to Table 2 for the design sections and Table 3 for the specifications of the blended base.

Section	Blended Base Depth	HBP-Class 31 Depth	Depth of Geogrid	Width of Geogrid
1 (Control)	18”	5.5”	N/A	N/A
2	18”	5.5”	11.5”	42’-8”
3	12”	5.5”	11.5”	42’-8”

Table 2

Class 3 Modified (Virgin Aggregate Used to Blend with Recycled Asphalt)	
Sieve Size	**Percent Passing**
1”	100
#4	35-85
#30	20-50
#200	4-10
Shale content	12% Maximum
Blended Base Course and Salvaged Base Course Gradation	
Sieve Size	**Percent Passing**
1 1/2”	100
1”	90-100

Table 3

The geogrid comes in two widths, 9.8’ and 13.1’. The manufacturer recommends a one-foot overlap of the material unless the subgrade is extremely weak and then a three-foot overlap is recommended. A one-foot overlap of the material was utilized. Refer to Figure 2 for the typical sections.

Section 1 (Control)
5.5" Class 31 HBP
18" Blended Base

Section 2
5.5" Class 31 HBP
18" Blended Base
Geogrid placed 6" below top of Blended Base

Section 3
5.5" Class 31 HBP
12" Blended Base
Geogrid placed 6" below top of Blended Base

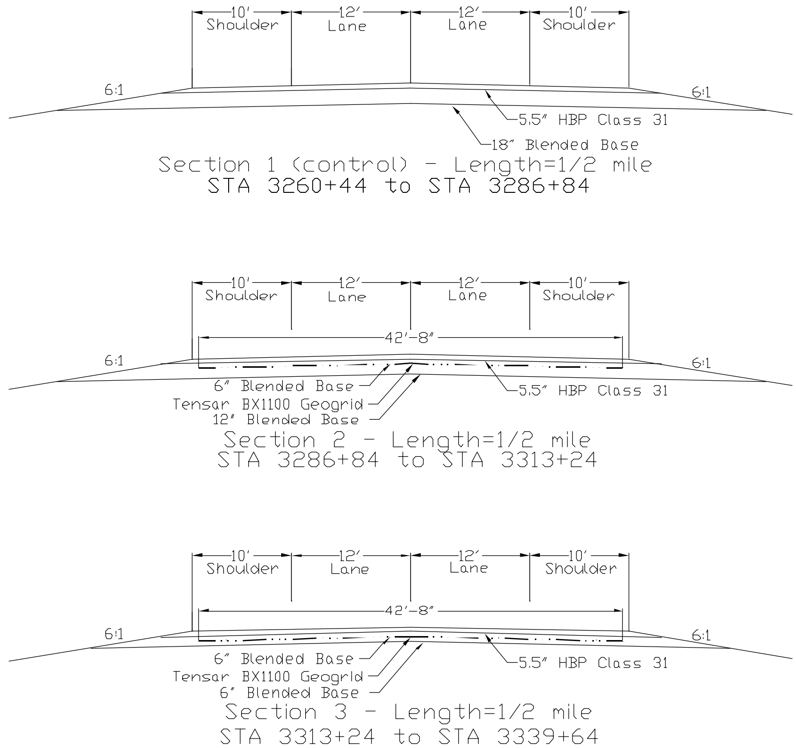


Figure 2 - Typical sections.

Construction

The experimental sections on this project were selected in 2002. They were determined by Materials and Research personnel after studying the project terrain and soil types indicated in the Linear Soils Report. The soils report is found in Appendix A. The area selected for the experimental sections had the most uniform soils.

The Tensar Geogrid BX1100 was sampled and sent to an independent laboratory for testing prior to installation. The geogrid passed the strength requirements of the certification. Copies of the test results are located in Appendix C. The original design called for a blended base (50% salvaged HBP and 50% virgin aggregate), however, to save cost and time, Class 5 was used on top of the geogrid in Section 1 and Section 2 instead of the blended base. Section 3 used Class 5 above and below the geogrid.

The contractor began spreading the base material in Section 2 on July 28, 2003. Each section was constructed as shown in the typical sections, which are located in the design section of this report.

Steve Madaus of Contech Construction Products, Inc. was on site at the project to direct the geogrid installation. When the required base thickness was laid and compacted, the geogrid was rolled out. The geogrid was overlapped by a minimum of 1 foot. Steve said that it is ok to drive on the geogrid but to avoid stopping, sharp turning, or spinning wheels.

The geogrid rolls were 13.1 feet wide. The stiffness of the geogrid helped to keep the material even and tight. The upper base material was placed on top of the geogrid with belly-dump trucks. The geogrid had a tendency to roll or cause a slight wave ahead of the tires if the truck was moving too fast. The geogrid would then become uneven in these areas. Base material was used in these areas to hold it down. This made it easier for the blade to spread the windrow. There were a few places where the uneven geogrid could not be smoothed out enough and was cut to lay flat and then covered with a geogrid patch. Another method was to fold the material under to take up the slack. The geogrid is supplied in rolls and has a tendency to roll back up. The contractor used large headed nails in some cases to hold down the geogrid. Photo 3 shows a roll of Tensar BX-1100 Geogrid.

Photo 3 – A roll of Tensar Geogrid BX 1100.

The geogrid installation is shown in the following photos.

Photo 4 – Starting new roll of geogrid

Photo 5 – Nailing down overlap of new roll, rolling out geogrid, and spreading base material.

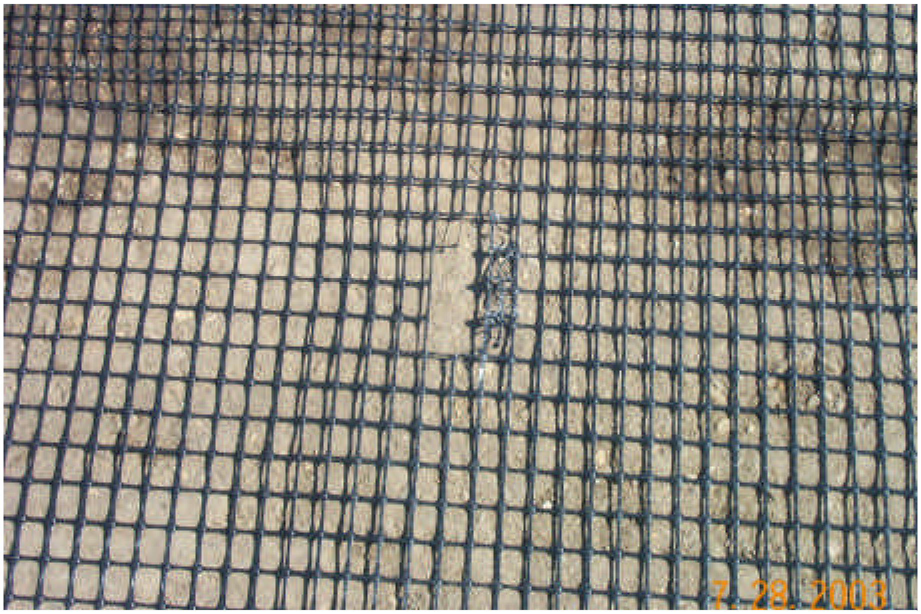


Photo 6 - Damaged areas like this can be repaired by overlaying with a 3'x3' patch.

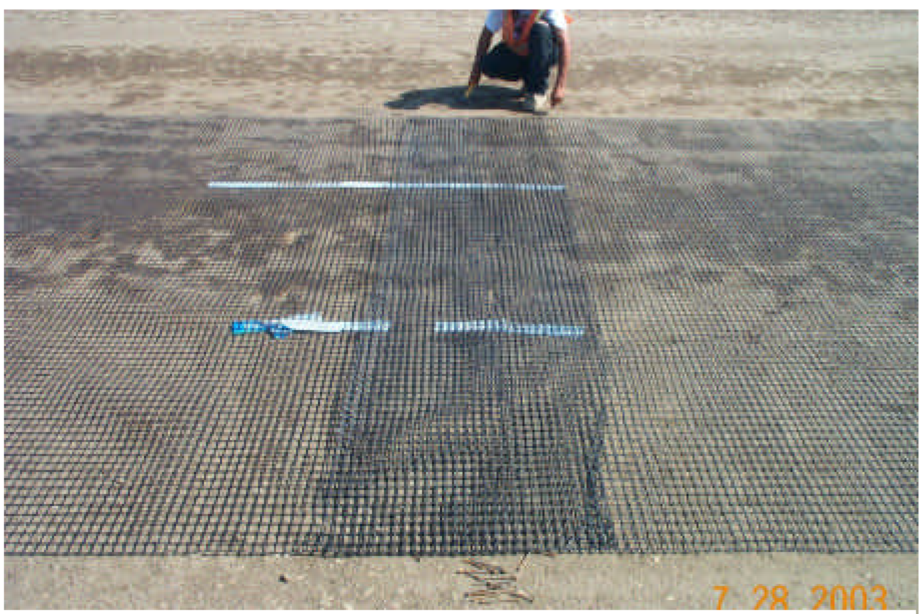


Photo 7 – Overlapping two rolls of geogrid and staking down edges.

Photo 8 – Placing the base material on the geogrid.

Photo 9 – Spreading base – notice the base material on the geogrid. It keeps the ends down so it stays in place.

Photo 10 – Some waves in the geogrid – nailing overlap area

Photo 11 - Compacting the base material on top of the geogrid.

Costs

The cost of each of the three sections is shown below.

Section 1 (Control): Sta. 3260+44 to 3286+84
9.5 inch Blended Base
8.5 inch Class 5
$90,290.11

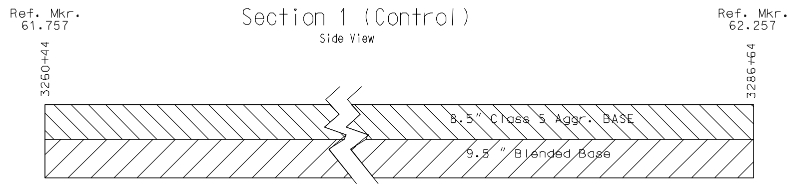
Section 2: Sta. 3286+84 to 3313+24
9.5 inch Blended Base
8.5 inch Class 5
42.67 ft. wide Geogrid
$121,581.50

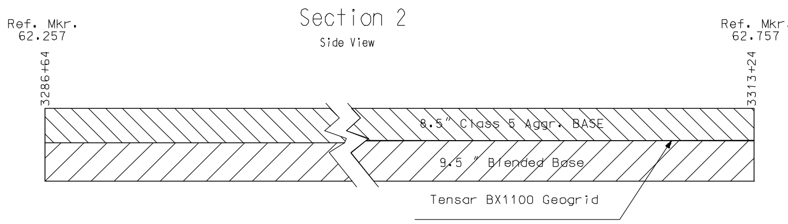
Section 3: Sta. 3313+24 to 3339+64
12 inch Class 5
42.67 ft. wide Geogrid
$82,944.84

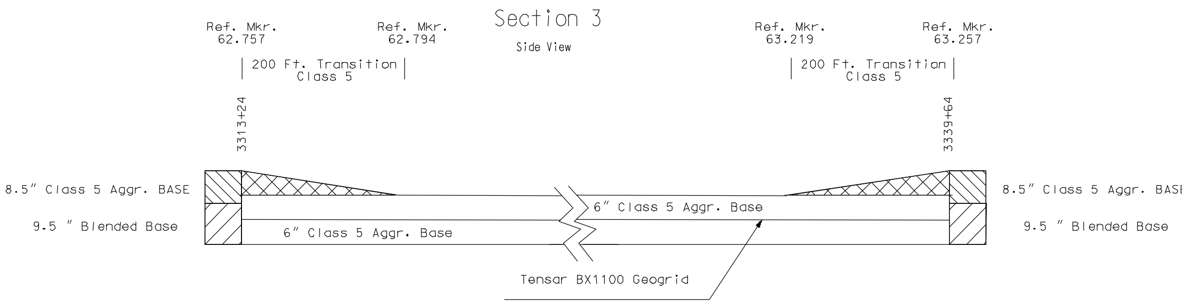
Test Sections 2 and 3 used 25,037 square yards of geogrid. An additional 780 tons of Class 5 at $4.90 per ton was used on Test Section 3 to fill the slough to the 72 foot graded shoulder. Comparing the Control Section to Section 3, $90,290.11 - $82,944.84 = a savings of $7,345.27 by substituting geogrid for 6" of base material. The geogrid was bid at $2.50 per square yard and included full compensation for all labor, equipment and materials to complete the work.

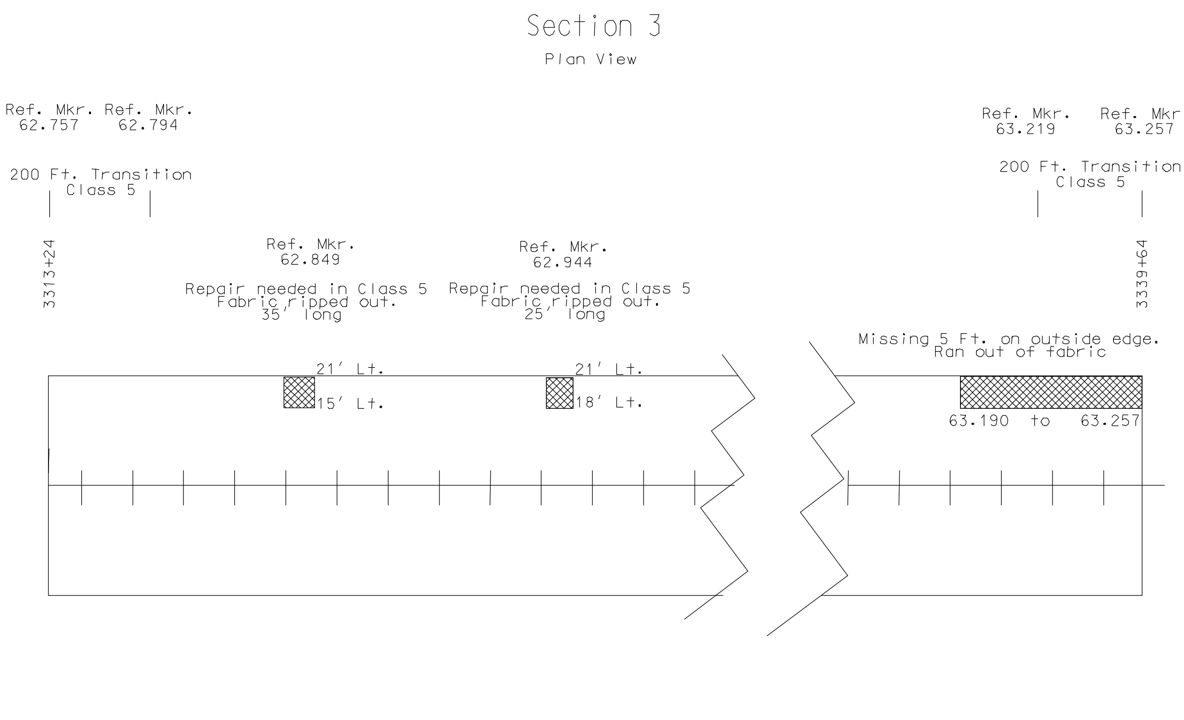
Construction Views

Three construction side views and one plan view were drawn and are shown on the next page. The views show the station limits and the layer thicknesses as constructed. Section 3 side view shows how the transitions were constructed. Section 3 plan view shows the areas were the geogrid was damaged and repaired. It also shows one area that contains no geogrid. Should any problems show up in the future, this view may help to identify the cause.


Section 1 (Control)
Side View
Ref. Mkr. 61.757
Ref. Mkr. 62.257
3260+44
3286+64
8.5" Class 5 Aggr. BASE
9.5 " Blended Base


Section 2
Side View
Ref. Mkr. 62.257
Ref. Mkr. 62.757
3286+64
3313+24
8.5" Class 5 Aggr. BASE
9.5 " Blended Base
Tensar BX1100 Geogrid


Section 3
Side View
Ref. Mkr. 62.757
Ref. Mkr. 62.794
Ref. Mkr. 63.219
Ref. Mkr. 63.257
200 Ft. Transition Class 5
200 Ft. Transition Class 5
3313+24
3339+64
8.5" Class 5 Aggr. BASE
9.5 " Blended Base
6" Class 5 Aggr. Base
6" Class 5 Aggr. Base
8.5" Class 5 Aggr. BASE
9.5 " Blended Base
Tensar BX1100 Geogrid


Section 3
Plan View
Ref. Mkr. 62.757
Ref. Mkr. 62.794
Ref. Mkr. 63.219
Ref. Mkr. 63.257
200 Ft. Transition Class 5
200 Ft. Transition Class 5
3313+24
3339+64
Ref. Mkr. 62.849
Repair needed in Class 5 Fabric ripped out. 35' long
Ref. Mkr. 62.944
Repair needed in Class 5 Fabric ripped out. 25' long
Missing 5 Ft. on outside edge. Ran out of fabric
21' Lt.
15' Lt.
21' Lt.
18' Lt.
63.190 to 63.257

Falling Weight Deflectometer

The Falling Weight Deflectometer (FWD) is one tool that is used to help evaluate roadway systems. It drops a pre-selected load onto the pavement surface. The resulting deflection of the roadway system is measured and stored. The modulus of each layer is calculated from the data using the Elmod 5 program. The FWD is shown in photo 12.

Photo 12 – The FWD operation.

The FWD data was calculated and graphed. Graphs were produced showing the total deflection of each section and the modulus of the asphalt, base, and subgrade. These graphs are found in Appendix B.

The average modulus of each section layer is shown in Table 4.

Section	Average Modulus (ksi) 2003		
	Asphalt	Base	Subgrade
1 (Control)	1154	45	28
2	1105	31	28
3	1425	19	15

Table 4

The modulus is an indication of load carrying capacity. The load carrying capacity generally increases with a modulus increase. A base value used for design purposes is 20 ksi. All three sections meet this base design value.

The base and subgrade modulus in Section 3 is about one-half of Sections 1 and 2. This is most likely due to the thinner base section. The average deflection of Section 3, as shown in Table 5, is higher than Sections 1 and 2. This means Section 3 deflected more and thus results in lower modulus values. As a rule, when the deflections increase the modulus decreases.

The average deflection of each section is shown in Table 5.

Section	Average Deflection (Mils)
1 (Control)	15.77
2	18.02
3	26.79

Table 5

Summary

The NDDOT is looking for ways to improve the performance of bases in roadways, conserve aggregates, reduce future maintenance costs, and reduce time needed to rehabilitate the roadway. To meet this objective, geogrid base reinforcement was designed as an experimental feature in two sections on this project.

Three sections each one-half mile in length were constructed. Two sections used geogrid in the base and one was a control section. The three sections were built as shown in table 6. To save cost and time to the project, the original design was changed from a blended base to a Class 5. Sections 1 and 2 used Class 5 on top of the geogrid and Section 3 used Class 5 for the entire base thickness. See Table 6 below.

	Section Number		
	1	**2**	**3**
HBP	1.5”	1.5”	1.5”
Class 5	8.5”	8.5”	12”
Geogrid	none	42.67 ft wide	42.67 ft wide
Blended Base	9.5”	9.5”	None

Table 6

The geogrid installation was completed with minimal problems. Tears in the geogrid had to be patched in a few areas. Some waves did occur in the geogrid if aggregate dumping or spreading of the aggregate was done too fast. Overall the geogrid installation went very well.

A 1½” lift of asphalt was placed on the compacted base and served as the driving surface until the final asphalt lift is placed in 2004. Load testing was conducted with the FWD on the three sections. The base modulus of each section was computed from test data and either met or passed the design value.

Appendix A

Linear Soil Report and Recommendations

Project: HPP-4-052(044)058

Donnybrook to Carpio
Project Length: 9.2 Miles
Project Limits: 59.6 to 68.8

Borings are from RP 58+4000 feet to 68+1270 feet
Ward/Renville County

June 5, 2002

*The beginning project limit of 59.6 was given to us by Kadrmas, Lee & Jackson. This does not match up with reference point 58 in the project number. The beginning limit of this project is the ending limit of the HPP-4-052(042)050 project.

SOIL CLASSIFICATION AND COMMENTS

A total of 64 samples were analyzed from the above-mentioned location at depths ranging from 1.5 to 9.0 feet below the pavement surface. The results are as follows:

Quantity	AASHTO Class	In-Place Moisture Range (%)	In-Place Moisture Average (%)	T-180 Optimum Moisture Average (%)	Plastic Limit Range (%)	Plastic Limit Average (%)
1	A-2-4	NA	8.5	11.0	NA	16
6	A-4	8.2-13.6	10.4	9.5	16-20	18
41	A-6	8.2-22.1	16.3	10.8	15-20	17
16	A-7-6	13.2-23.5	17.9	11.9	15-22	18

AASHTO Class	Plastic Index Range (%)	Plastic Index Average (%)	Liquid Limit Range (%)	Liquid limit Average (%)
A-6	10-21	16	27-39	33
A-7-6	21-30	25	40-50	43

Note: Moisture Contents provided in this report have been obtained from samples taken on 6/12/01 and 4/16/02.

SOIL CLASSIFICATION AND COMMENTS (Cont.)

Comparison of the In-Place Moisture Contents to the Plastic Limits at the 2, 3, and 4 foot depths are shown below:

	Quantity	Below Plastic Limit	Plastic Limit to 5% Above	More than 5% Above Plastic Limit
2 Foot	50	76%	24%	None
3 Foot	55	62%	34%	4% (2 samples)
4 Foot	58	45%	50%	5% (3 samples)
5 Foot	9	67%	22%	11% (1 sample)
6 Foot	6	67%	33%	None
7 Foot	4	75%	25%	None
8 Foot	3	67%	33%	None
9 Foot	1	None	100%	None

The Plastic Index values ranged from 6 to 30. The swell potential, based on the Plastic Index (PI) results, is shown below:

Swell Potential		
Low (PI<25)	**Marginal** (25<PI<35)	**High** (PI>35)
86%	14% (9 samples)	None

Frost Susceptibility:
None of the samples were classified as F4 soils (Highly Frost Susceptible).

Group Index:
The A-6 and A-7-6 Group Indexes ranged from a low of 0 to a high of 23 with an average of 8. A group index of 20 or greater indicates a “very poor” sub-grade material. Only two samples from this project were above 20.

SOIL CLASSIFICATION AND COMMENTS (Cont.)

Moisture samples were taken at all boring locations. The results are as follows:

Depth	Quantity	In-Place Moisture Range (%)	In-Place Moisture Average (%)
2 Foot	105	2.1-16.0	9.7
3 Foot	114	2.2-22.9	11.2
4 Foot	117	1.8-28.6	11.7
5 Foot	10	10.0-21.7	15.3
6 Foot	7	6.3-17.6	12.5
7 Foot	5	12.1-17.4	14.8
8 Foot	3	16.5-19.4	17.5
9 Foot	1	NA	17.1

Moisture content at the 2, 3, and 4 foot depths were determined using analyzed samples and have been compared to the optimum moisture content as determined by the AASHTO T-180 specifications. In-Place Moisture vs. Optimum Moisture results are shown in the following table.

In-Place Moisture vs. Optimum Moisture						
Quantity	**AASHTO Class.**	**Below Optimum**	**Optimum to Moderate** (0 to 6% over optimum)	**Moderate to High** (6 to 10% over optimum)	**High** (10 to 16% over optimum)	**Very High** (>16% over optimum)
1	A-2-4	None	100%	None	None	None
6	A-4	33%	67%	None	None	None
41	A-6	2%	56%	39%	2% (1 sample)	None
16	A-7-6	None	38%	62%	None	None

SOIL CLASSIFICATION AND COMMENTS (Cont.)

Summary of Findings:
Four percent of the 3 foot, 5% of the 4 foot, and 11% (1 sample) of the 5 foot samples had a moisture content in the “More than 5% Above the Plastic Limit” range.

Eighty-six percent of the sample had low swell potential. The remaining samples possessed marginal swell potential.

The In-Place moisture contents at the two, three, and four foot depths were 11.2%, 11.7%, and 15.3%, respectively.

One A-6 sample had a moisture content in the “High” (10%-16% over optimum) category.

Maintenance Problem Areas:
On June 12th, 2001, Monte Babeck, Drill Crew Chief, and Monte Lee, Minot District Maintenance Coordinator, met and reviewed the project. A general observation of the pavement revealed several depressed, transverse cracks. The following areas were mentioned by Mr. Lee as problem areas.

-RP 63+0500 to RP 63+0700: This area has been blade patched multiple times because of settlement and a dip forming over a culvert.
-RP 63+2800 to RP 63+3200: A blade patch and chip seal have been placed in this area. The main types of distress were alligator cracking and secondary cracking. Pieces of asphalt have broken away in some area.
-RP 66+2500 to RP 67+0000: This area is located on the backside of a hill. Blade patching and scotch patching have been performed here. Alligator cracking was part of the reason for the patching.
-RP 67+0000 to RP 68+0000: This area has multiple blade patches due to rutting, shoving, and depressed cracks.

Water was found adjacent to the roadway in the following areas.

-RP 60+0700 to RP 60+1700: Water present South of the roadway 7-8 feet below road grade.
-RP 65+0000 to RP 65+1300: Water present South of the roadway 7-8 feet below road grade.
-RP 65+3400 to RP 65+4100: Water present South of the roadway 7-8 feet below road grade.
-RP 67+1100 to RP 67+1800: Water present North of the roadway 5-6 feet below road grade.

SOIL CLASSIFICATION AND COMMENTS (Cont.)

Roadway Pavement Section:
This section of roadway was originally graded in 1947. In 1947, 2.0 inches of asphalt was placed on 5.0 inches of stabilized base. Since then four 1.5 inch overlays have been placed from the years of 1956 to 1986. A contract sand seal was placed in 1988 and a 1.0 inch intermittent contract patch was placed in 1994.

This is to be a grade/aggregate base project. The proposed pavement section is 5.5 inches of HBP, placed upon 18 inches of dense graded base.

Maintenance costs totaled $74,568 from RP 59 to 68, during the years of 1992 through 2000. The average cost per mile per year was $828. The most work was performed in miles 66 and 67. In mile 66 $19,158 was spent over the 9 years, averaging $2,129 of maintenance per year. Mile 67 had $14,914 in maintenance, with an average of $1,657 per year. The majority of the work performed in these miles were in the form of bituminous overlays/blade patching.

DESIGN RECOMMENDATIONS

Subcut Recommendations:
We recommend subcutting the first area due to the presence of organics and high moisture content at the three foot depth. The remaining 18" subcuts are recommended because of past maintenance problems, poor soil properties uncovered during the soil analysis, or a combination of the the two.

Note: To account for unforseen poor subgrade conditions we recommend allowing an additional 1,000 feet of 18" subcut to be used at the discretion of the Project Engineer.

Note: We recommend that subcuts be performed with a backhoe using a smooth cutting edge to minimize disturbance to underlying soils. In addition, we recommend that construction equipment with heavy tire pressures traveling over the following soft subgrade areas be kept to a minimum to prevent additional moisture from pumping up.

RP + Feet	to	RP + Feet	Remarks
60+3250		60+3750	Subcut to a depth of 36" below the newly proposed grade. Place Reinforcement fabric (R1) at the bottom of all subcut excavations and backfill with Class 3, Class 5, or salvaged aggregate. Place a minimum of 12" of aggregate on the fabric prior to compacting. Do not scarify the bottom of the subcut.
Total 36" Subcut Length=500 feet			
63+2800		63+3200	Subcut to a depth of 18" below the newly proposed grade. Place Reinforcement fabric (R1) at the bottom of all subcut excavations and backfill with Class 3, Class 5, or salvaged aggregate. Place a minimum of 12" of aggregate on the fabric prior to compacting. Do not scarify the bottom of the subcut.
68+0600		68+1000	
Proposed 18" Subcut Length=800 feet			
Additional 18" Subcut Length=1000 feet			
Total 18" Subcut Length=1800 feet			

Notes: A 20:1 transition must be constructed prior to entering and on exiting subcut and culvert or box culvert sections to avoid differential heave.

Compaction of aggregate for subgrade repair should comply with NDDOT Standard Specification 302.04 E.

If areas of free water are encountered during construction drainage must be provided. Materials and Research can be contacted for drainage design.

DESIGN RECOMMENDATIONS (Cont.)

Subgrade Preparation:
We recommend 12" Subgrade Preparation on this project. Subgrade Preparation should comply with NDDOT Standard Specification 230.02 B.5, **Type C (12")**. Compaction control should be in accordance with NDDOT Specification 203.02 G, Type A, and also with AASHTO T-180.

Pipe Installation:
The culvert located within the area of RP 63+0500 to RP 63+0700 should be rebuilt according the current pipe detail. Attached is a copy of the pipe installation detail that should be followed for all pipe replacements.

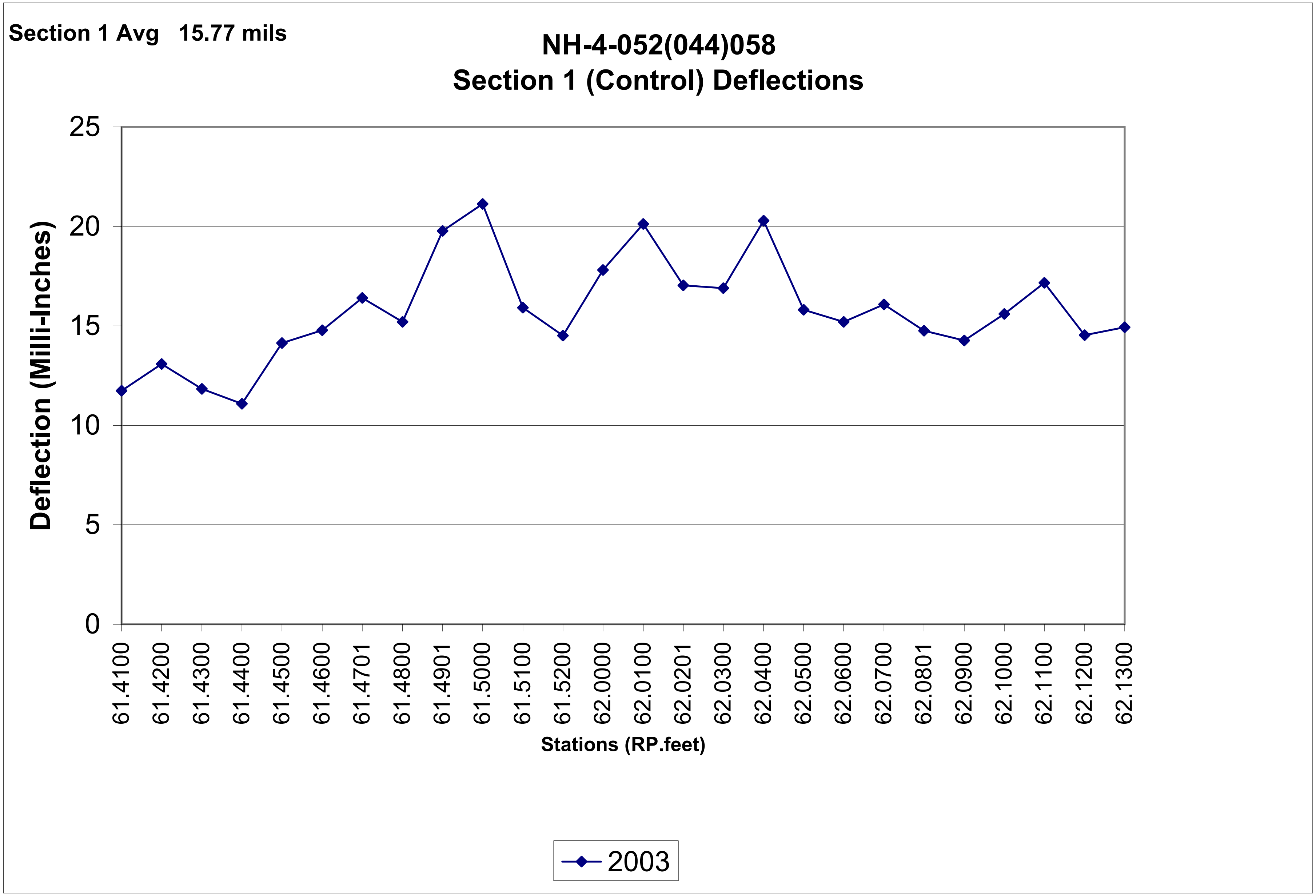
If the vertical profile or horizontal alignment is changed in either the conceptual phase or the design phase, Materials and Research must be notified as soon as possible to ensure that there is adequate geotechnical information addressing these areas.

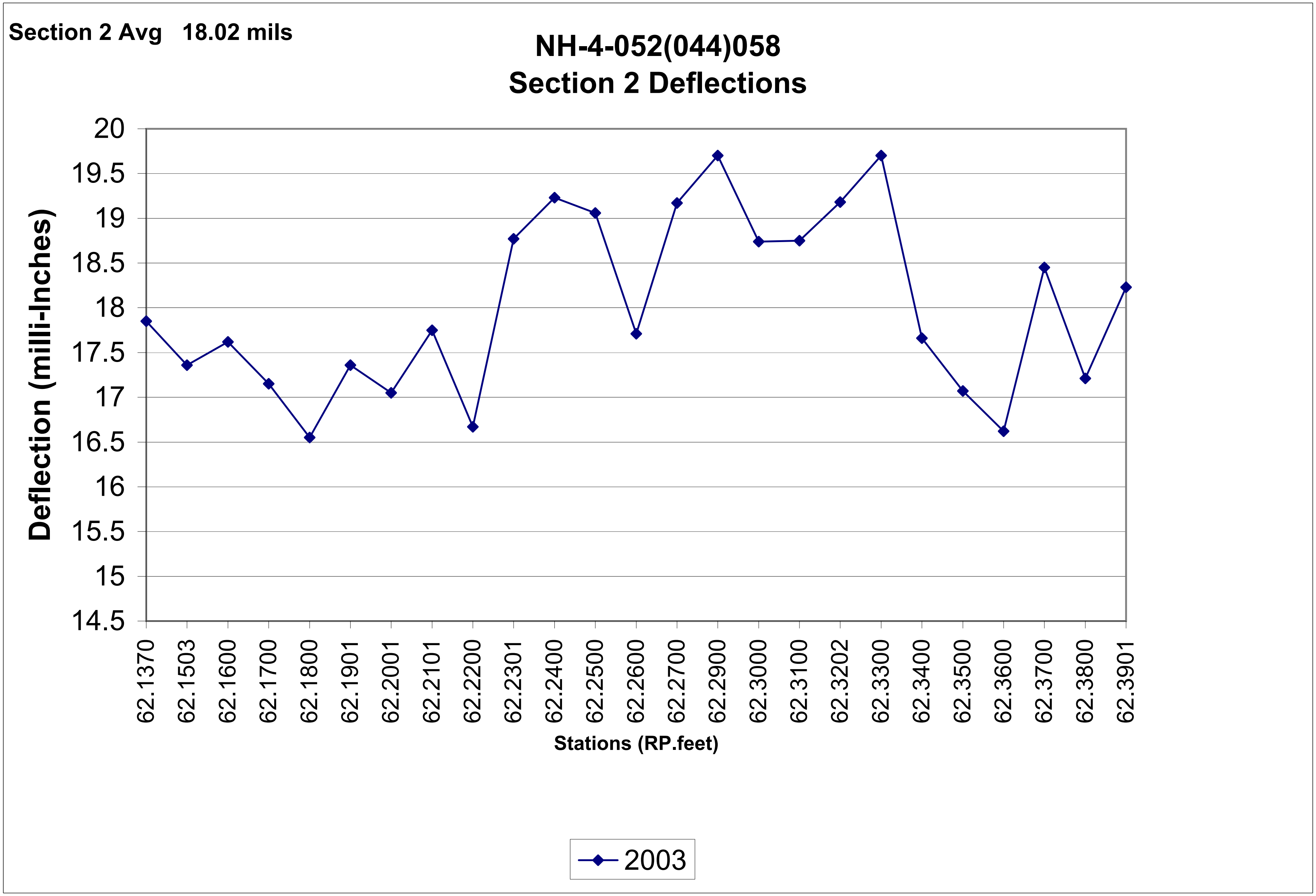
The information in this report is based on the grading/aggregate base option. If the proposed improvement changes, reassessment of our recommendations will be necessary.

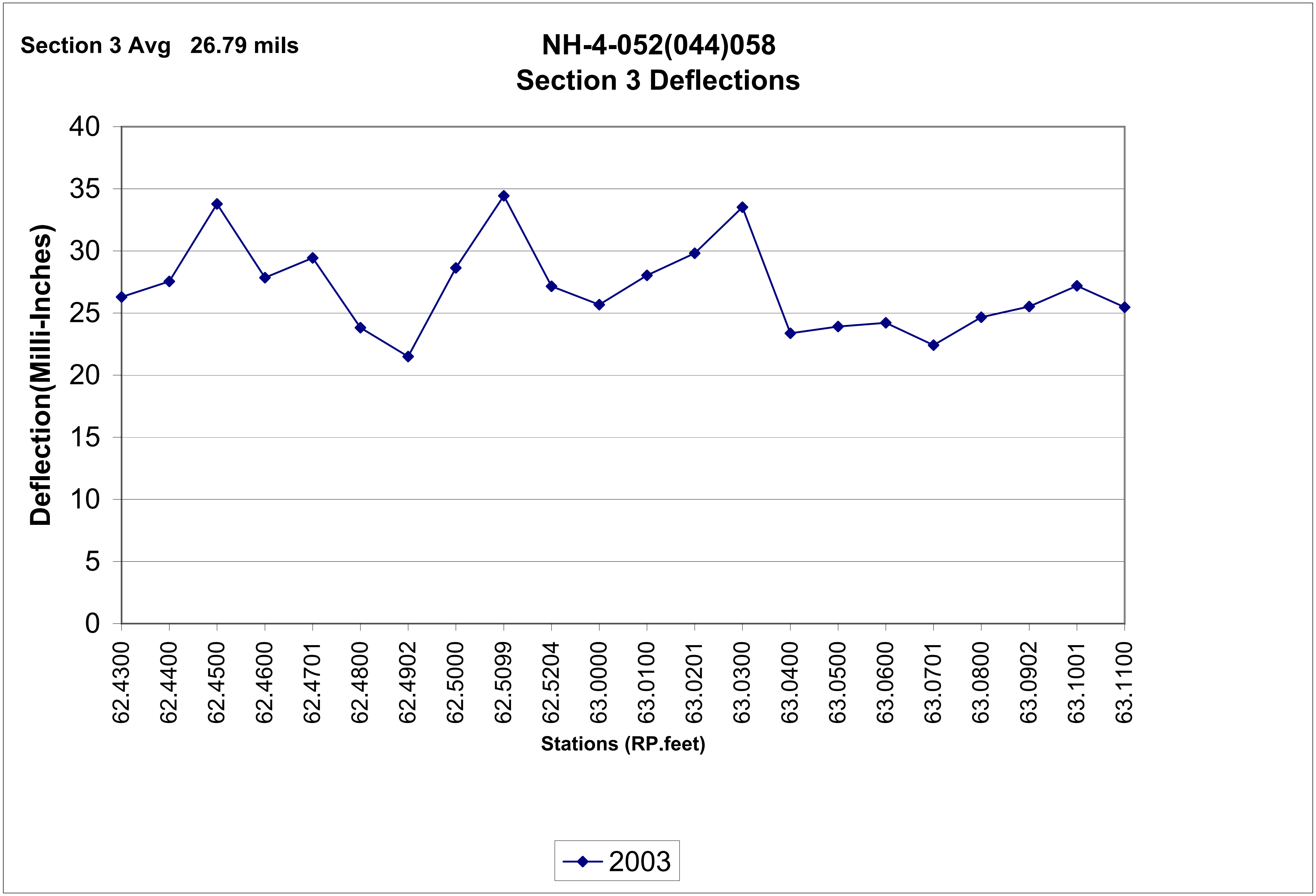
Please contact me at 328-6907 or Jon Ketterling at 328-6908 if there are any questions or modifications to the plans for rehabilitation of this roadway.

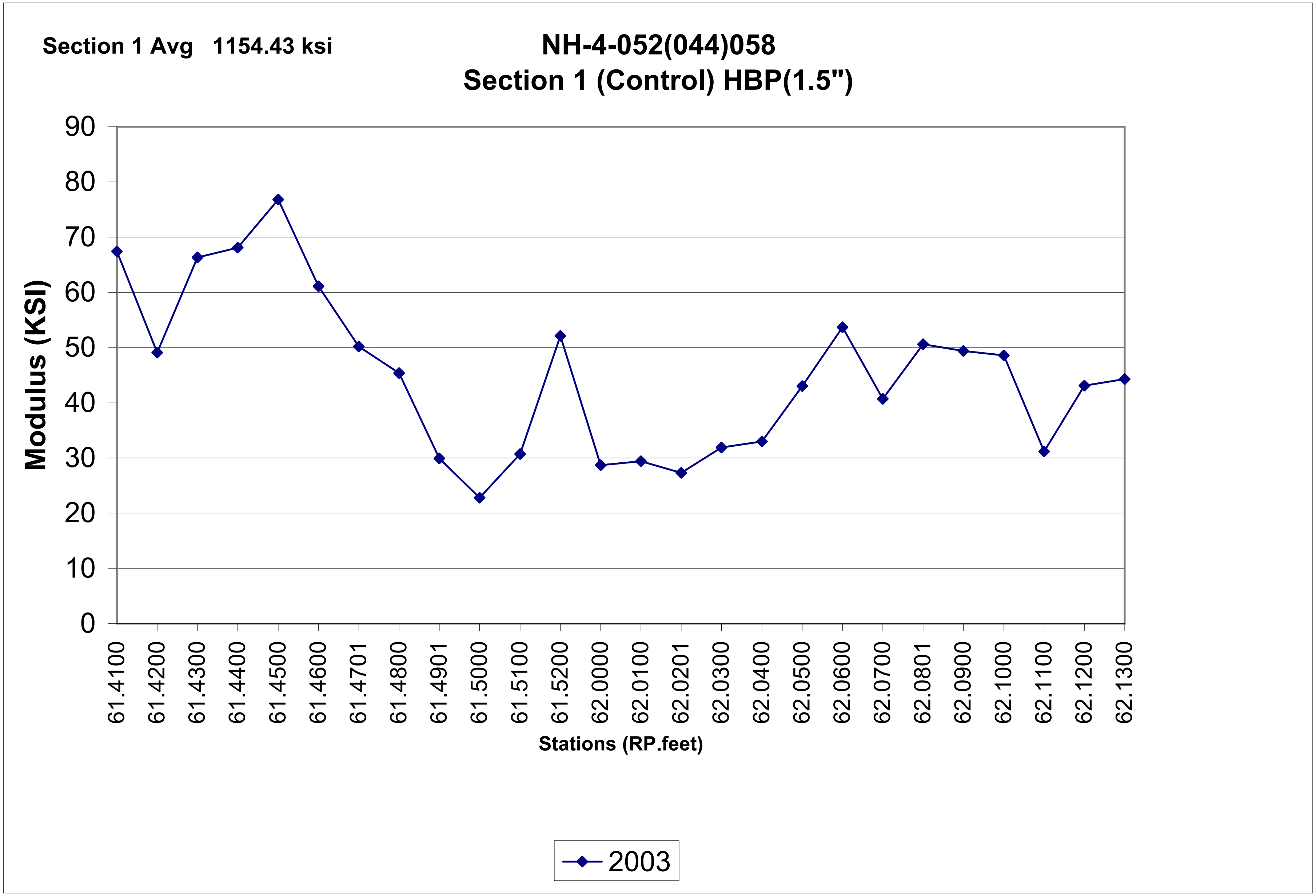
Benjie Foss
Geotechnical Section

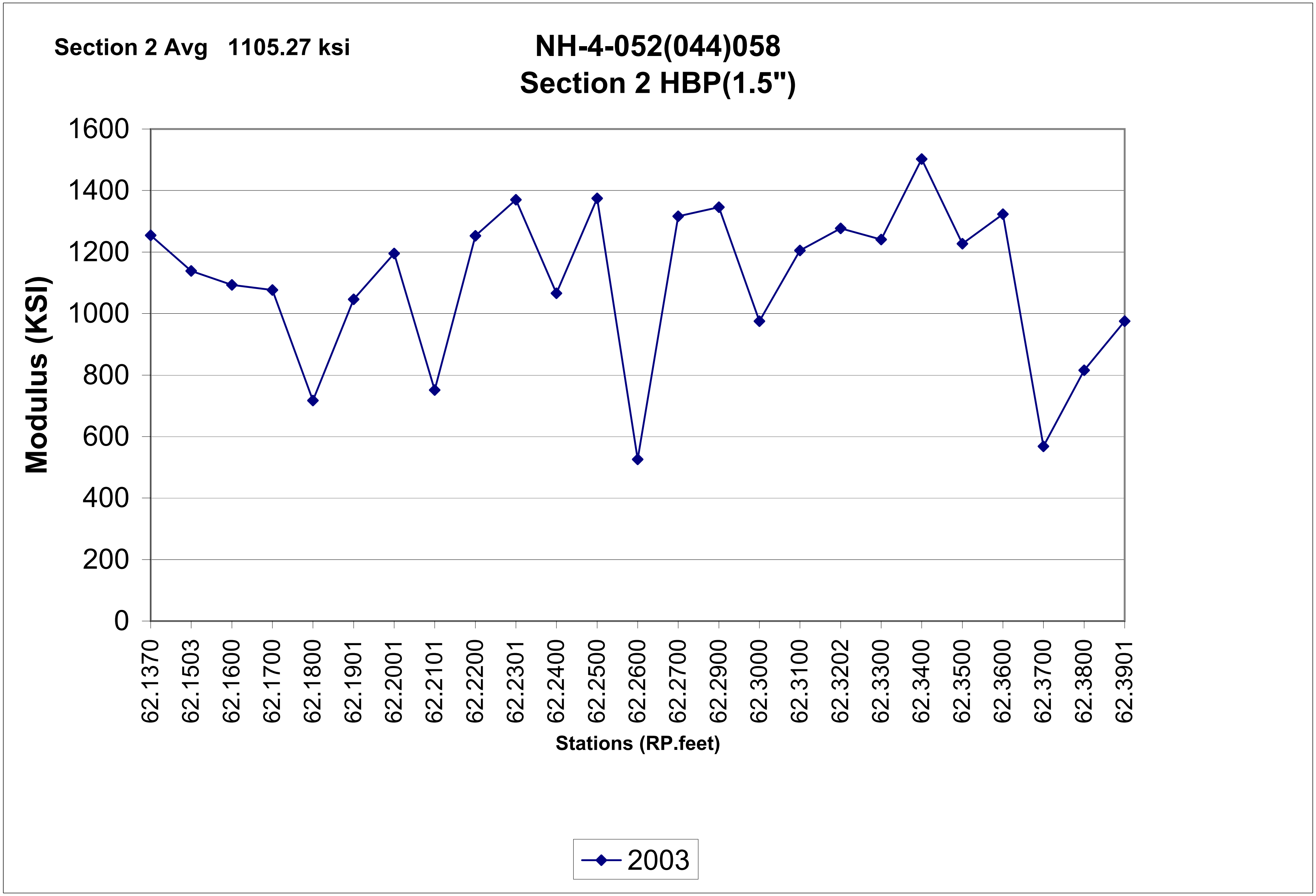
Appendix B


Section 1 Avg 15.77 mils
NH-4-052(044)058
Section 1 (Control) Deflections
Deflection (Milli-Inches)
25
20
15
10
5
0
61.4100
61.4200
61.4300
61.4400
61.4500
61.4600
61.4701
61.4800
61.4901
61.5000
61.5100
61.5200
62.0000
62.0100
62.0201
62.0300
62.0400
62.0500
62.0600
62.0700
62.0801
62.0900
62.1000
62.1100
62.1200
62.1300
Stations (RP.feet)
2003

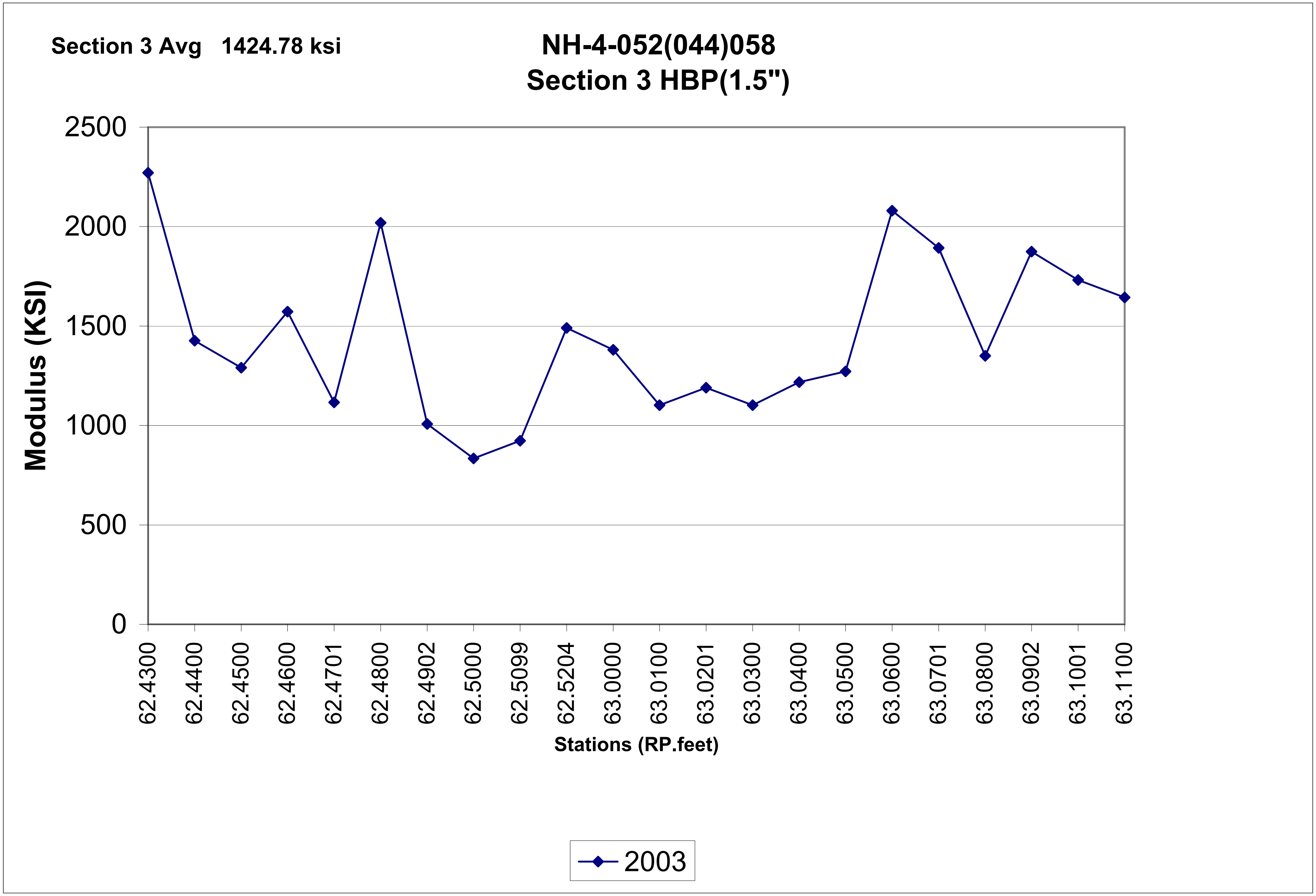

Section 2 Avg 18.02 mils
NH-4-052(044)058
Section 2 Deflections
Deflection (milli-Inches)
20
19.5
19
18.5
18
17.5
17
16.5
16
15.5
15
14.5
62.1370
62.1503
62.1600
62.1700
62.1800
62.1901
62.2001
62.2101
62.2200
62.2301
62.2400
62.2500
62.2600
62.2700
62.2900
62.3000
62.3100
62.3202
62.3300
62.3400
62.3500
62.3600
62.3700
62.3800
62.3901
Stations (RP.feet)
2003

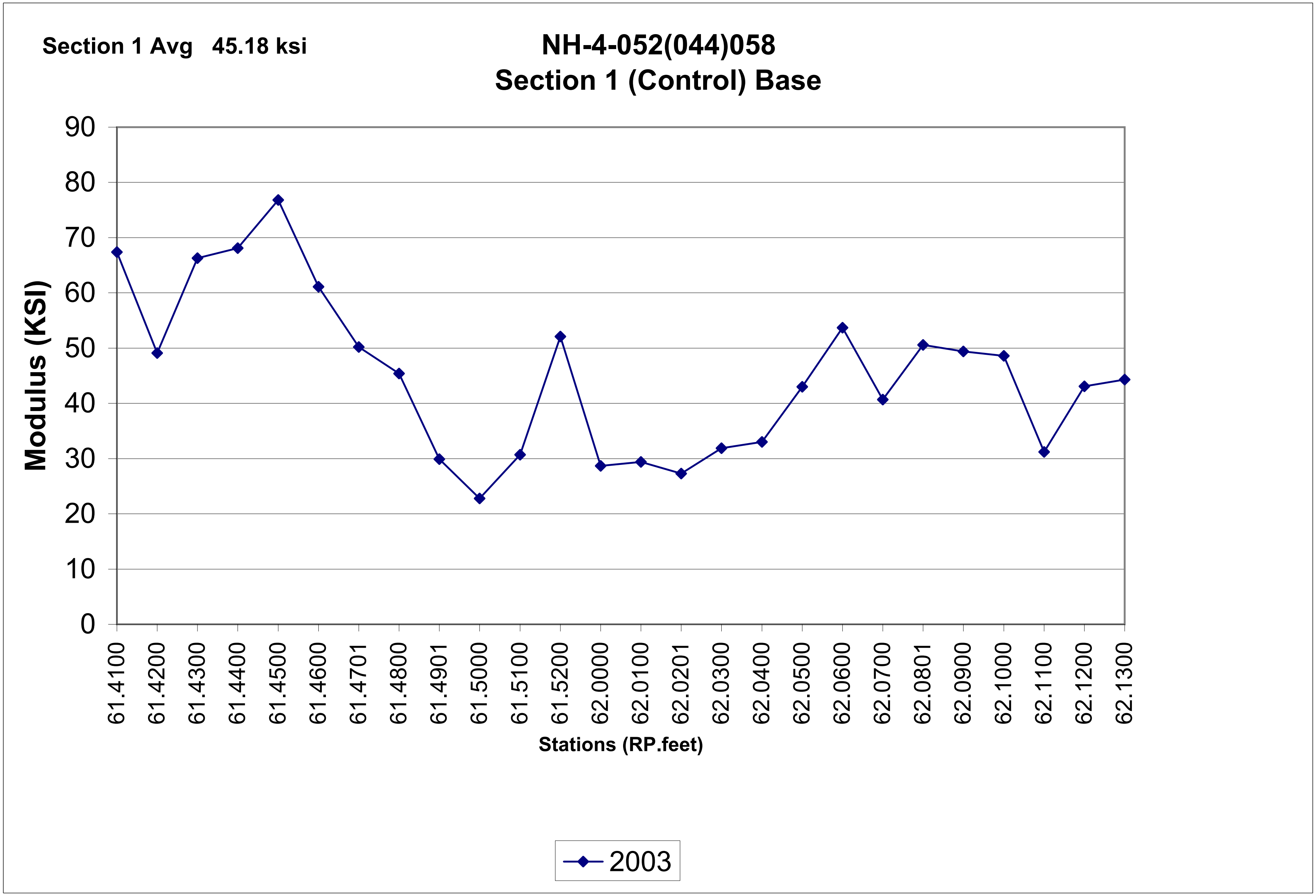

Section 3 Avg 26.79 mils
NH-4-052(044)058
Section 3 Deflections
Deflection(Milli-Inches)
40
35
30
25
20
15
10
5
0
62.4300
62.4400
62.4500
62.4600
62.4701
62.4800
62.4902
62.5000
62.5099
62.5204
63.0000
63.0100
63.0201
63.0300
63.0400
63.0500
63.0600
63.0701
63.0800
63.0902
63.1001
63.1100
Stations (RP.feet)
2003


Section 1 Avg 1154.43 ksi
NH-4-052(044)058
Section 1 (Control) HBP(1.5")
Modulus (KSI)
90
80
70
60
50
40
30
20
10
0
61.4100
61.4200
61.4300
61.4400
61.4500
61.4600
61.4701
61.4800
61.4901
61.5000
61.5100
61.5200
62.0000
62.0100
62.0201
62.0300
62.0400
62.0500
62.0600
62.0700
62.0801
62.0900
62.1000
62.1100
62.1200
62.1300
Stations (RP.feet)
2003

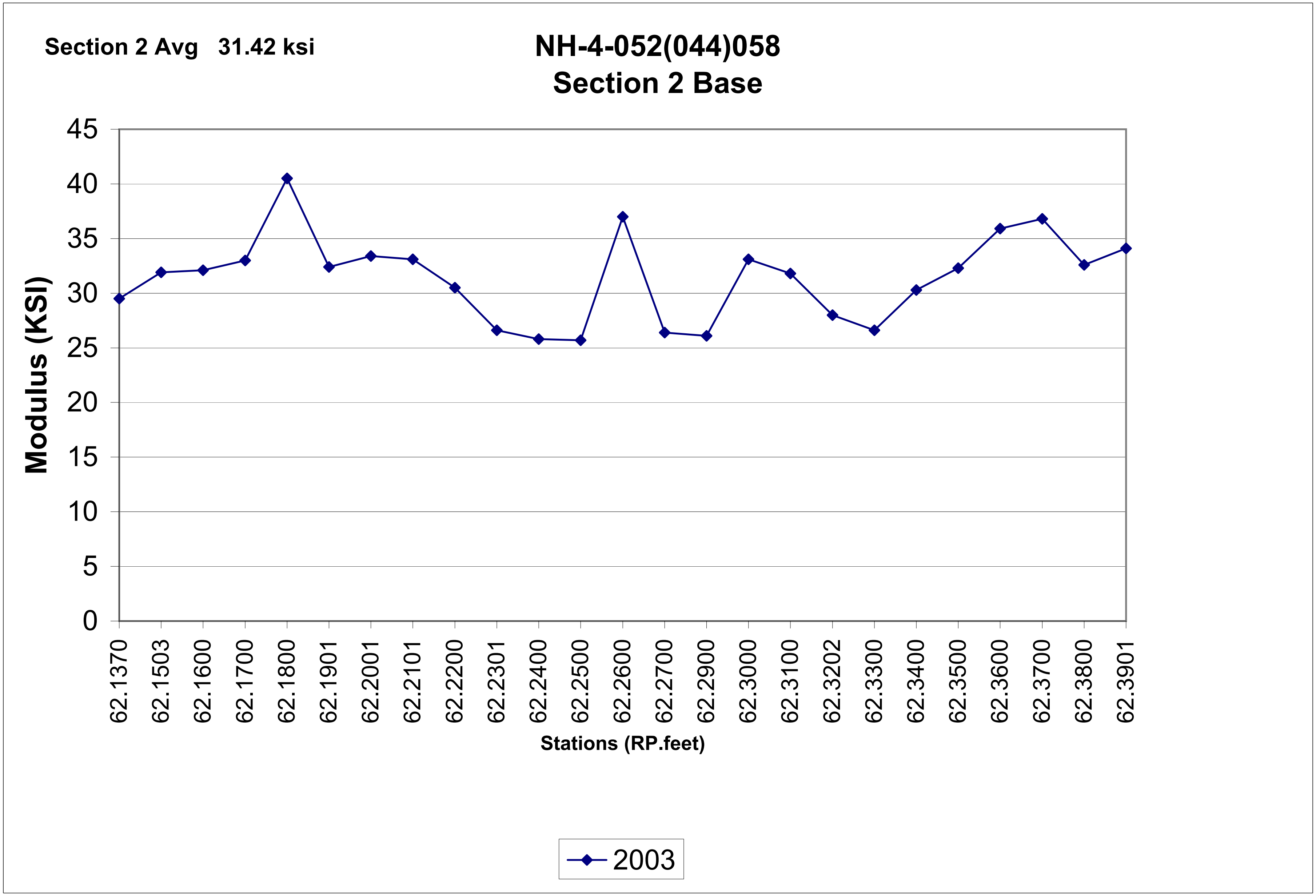


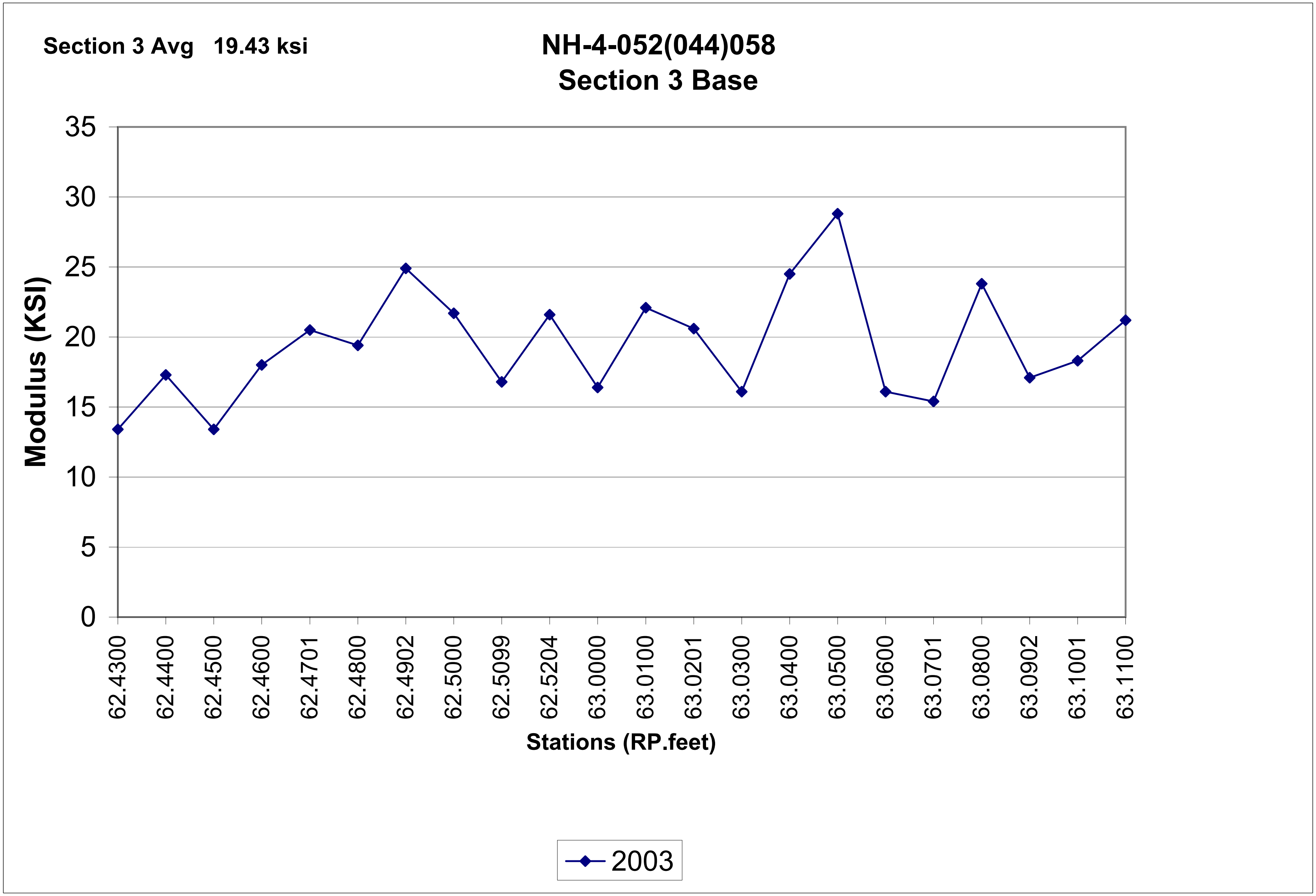
Section 2 Avg 1105.27 ksi
NH-4-052(044)058
Section 2 HBP(1.5")
Modulus (KSI)
1600
1400
1200
1000
800
600
400
200
0
62.1370
62.1503
62.1600
62.1700
62.1800
62.1901
62.2001
62.2101
62.2200
62.2301
62.2400
62.2500
62.2600
62.2700
62.2900
62.3000
62.3100
62.3202
62.3300
62.3400
62.3500
62.3600
62.3700
62.3800
62.3901
Stations (RP.feet)
2003


Section 3 Avg 1424.78 ksi
NH-4-052(044)058
Section 3 HBP(1.5")
Modulus (KSI)
2500
2000
1500
1000
500
0
62.4300
62.4400
62.4500
62.4600
62.4701
62.4800
62.4902
62.5000
62.5099
62.5204
63.0000
63.0100
63.0201
63.0300
63.0400
63.0500
63.0600
63.0701
63.0800
63.0902
63.1001
63.1100
Stations (RP.feet)
2003

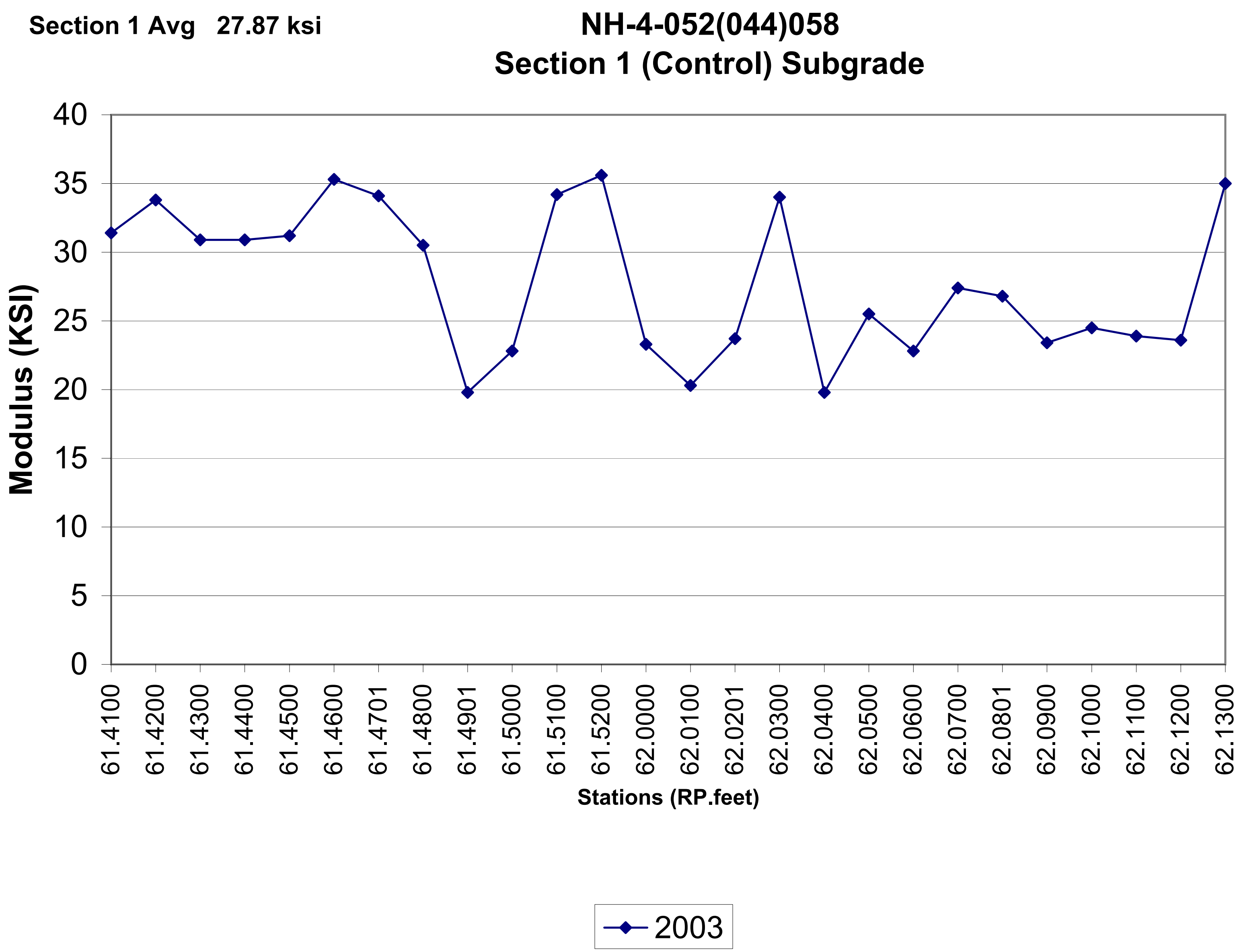


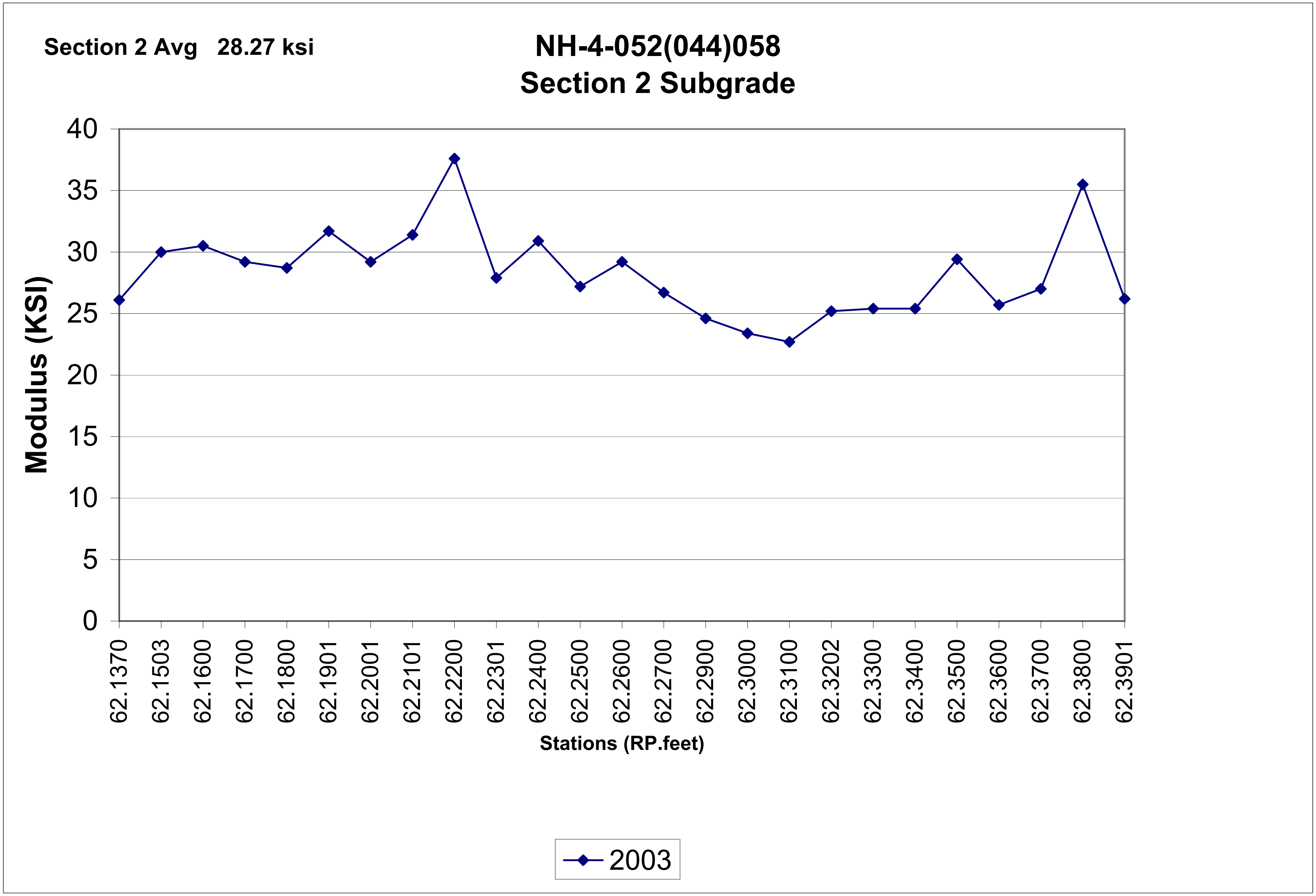
Section 1 Avg 45.18 ksi
NH-4-052(044)058
Section 1 (Control) Base
Modulus (KSI)
90
80
70
60
50
40
30
20
10
0
61.4100
61.4200
61.4300
61.4400
61.4500
61.4600
61.4701
61.4800
61.4901
61.5000
61.5100
61.5200
62.0000
62.0100
62.0201
62.0300
62.0400
62.0500
62.0600
62.0700
62.0801
62.0900
62.1000
62.1100
62.1200
62.1300
Stations (RP.feet)
2003


Section 2 Avg 31.42 ksi
NH-4-052(044)058
Section 2 Base
Modulus (KSI)
45
40
35
30
25
20
15
10
5
0
62.1370
62.1503
62.1600
62.1700
62.1800
62.1901
62.2001
62.2101
62.2200
62.2301
62.2400
62.2500
62.2600
62.2700
62.2900
62.3000
62.3100
62.3202
62.3300
62.3400
62.3500
62.3600
62.3700
62.3800
62.3901
Stations (RP.feet)
2003


Section 3 Avg 19.43 ksi
NH-4-052(044)058
Section 3 Base
Modulus (KSI)
35
30
25
20
15
10
5
0
62.4300
62.4400
62.4500
62.4600
62.4701
62.4800
62.4902
62.5000
62.5099
62.5204
63.0000
63.0100
63.0201
63.0300
63.0400
63.0500
63.0600
63.0701
63.0800
63.0902
63.1001
63.1100
Stations (RP.feet)
2003

Section 1 Avg 27.87 ksi




Section 2 Avg 28.27 ksi
NH-4-052(044)058
Section 2 Subgrade
Modulus (KSI)
0
5
10
15
20
25
30
35
40
62.1370
62.1503
62.1600
62.1700
62.1800
62.1901
62.2001
62.2101
62.2200
62.2301
62.2400
62.2500
62.2600
62.2700
62.2900
62.3000
62.3100
62.3202
62.3300
62.3400
62.3500
62.3600
62.3700
62.3800
62.3901
Stations (RP.feet)
2003

Appendix C

geotechnics
INTEGRITY IN TESTING

TENSILE STRENGTH TEST RESULTS

ASTM D-6637

CLIENT: NORTH DAKOTA D.O.T.
CLIENT PROJECT: AC-HPP-4-052(044)058
PROJECT NO.: L03127-08
LAB IDNO.: L03127-08-01
MATERIAL: TENSAR BX1100 GEOGRID
SAMPLE: #1
LOT NO.: 071

TEST	UNITS	SPECIMEN NO. 1	2	3	4	5	AVG	STD
RIB COUNT	MD Ribs/ft	7.94						
	CD Ribs/ft	10.67						
WIDE WIDTH	2%-MD lbs/ft	253	313	301	297	287	**290**	22.66
STRENGTH	5%-MD lbs/ft	663	710	707	712	689	**696**	20.74
MD	Ult.-MD lbs/ft	941	944	946	961	966	**952**	11.09
	Elong at Peak-%	10	8	8	8	9	**9**	0.64
WIDE WIDTH	2%-CD lbs/ft	424	427	410	423	421	**421**	6.74
STRENGTH	5%-CD lbs/ft	1,033	1,027	1,015	1,028	1,024	**1,025**	6.55
CD	Ult.-CD lbs/ft	1,628	1,608	1,618	1,620	1,509	**1,597**	49.37
	Elong at Peak-%	12	12	13	12	9	**12**	1.37
RETEST								
WIDE WIDTH	2%-CD lbs/ft	440	439	441	418	446	**437**	11.10
STRENGTH	5%-CD lbs/ft	1,044	1,044	1,030	1,025	1,063	**1,041**	15.01
CD	Ult.-CD lbs/ft	1,593	1,650	1,525	1,498	1,649	**1,583**	69.74
	Elong at Peak-%	11	12	10	9	11	**11**	1.25

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INTEGRITY IN TESTING

TENSILE STRENGTH TEST RESULTS

ASTM D-6637

CLIENT: NORTH DAKOTA D.O.T.
CLIENT PROJECT: AC-HPP-4-052(044)058
PROJECT NO.: L03127-08
LAB IDNO.: L03127-08-02
MATERIAL: TENSAR BX1100 GEOGRID
SAMPLE: # 2
LOT NO.: 080

TEST	UNITS	SPECIMEN NO.					AVG	STD
		1	2	3	4	5		
RIB COUNT	MD Ribs/ft	7.94						
	CD Ribs/ft	10.63						
WIDE WIDTH	2%-MD lbs/ft	302	289	299	304	276	**294**	11.51
STRENGTH	5%-MD lbs/ft	710	691	693	704	689	**698**	9.09
MD	Ult.-MD lbs/ft	897	875	975	756	995	**900**	94.63
	Elong at Peak-%	7	7	10	6	10	**8**	2.05
WIDE WIDTH	2%-CD lbs/ft	439	485	490	469	534	**484**	34.75
STRENGTH	5%-CD lbs/ft	1,125	1,158	1,167	1,132	1,197	**1,156**	29.14
CD	Ult.-CD lbs/ft	1,605	1,661	1,637	1,454	1,624	**1,596**	82.12
	Elong at Peak-%	9	11	9	7	10	**9**	1.43

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INTEGRITY IN TESTING

TENSILE STRENGTH TEST RESULTS

ASTM D-6637

CLIENT: NORTH DAKOTA D.O.T.
CLIENT PROJECT: AC-HPP-4-052(044)058
PROJECT NO.: L03127-08
LAB IDNO.: L03127-08-03
MATERIAL: TENSAR BX1100 GEOGRID
SAMPLE: # 3
LOT NO.: 084

TEST	UNITS	SPECIMEN NO. 1	2	3	4	5	AVG	STD
RIB COUNT	MD Ribs/ft	7.94						
	CD Ribs/ft	10.33						
WIDE WIDTH STRENGTH MD	2%-MD lbs/ft	292	295	312	290	288	**295**	9.78
	5%-MD lbs/ft	706	705	717	708	691	**705**	9.28
	Ult.-MD lbs/ft	1,058	979	900	922	855	**943**	78.36
	Elong at Peak-%	17	9	7	8	7	**9**	4.09
WIDE WIDTH STRENGTH CD	2%-CD lbs/ft	504	476	446	471	490	**478**	21.73
	5%-CD lbs/ft	1,161	1,133	1,115	1,087	1,125	**1,124**	26.93
	Ult.-CD lbs/ft	1,587	1,505	1,532	1,537	1,475	**1,527**	41.69
	Elong at Peak-%	10	9	8	10	8	**9**	0.97

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INTEGRITY IN TESTING

TENSILE STRENGTH TEST RESULTS

ASTM D-6637

CLIENT: NORTH DAKOTA D.O.T.
CLIENT PROJECT: AC-HPP-4-052(044)058
PROJECT NO.: L03127-08
LAB IDNO.: L03127-08-04
MATERIAL: TENSAR BX1100 GEOGRID
SAMPLE: # 4
LOT NO.: 093

TEST	UNITS	SPECIMEN NO. 1	2	3	4	5	AVG	STD
RIB COUNT	MD Ribs/ft	7.94						
	CD Ribs/ft	10.38						
WIDE WIDTH STRENGTH MD	2%-MD lbs/ft	299	293	293	302	286	**294**	6.17
	5%-MD lbs/ft	708	700	698	708	689	**701**	7.85
	Ult.-MD lbs/ft	875	1,025	926	941	904	**934**	56.74
	Elong at Peak-%	7	11	8	8	8	**8**	1.58
WIDE WIDTH STRENGTH CD	2%-CD lbs/ft	477	479	480	447	438	**464**	19.95
	5%-CD lbs/ft	1,123	1,141	1,126	1,091	1,097	**1,115**	21.01
	Ult.-CD lbs/ft	1,566	1,414	1,564	1,551	1,576	**1,534**	67.88
	Elong at Peak-%	10	7	10	10	11	**10**	1.36

CHECKED BY: JB DATE: 6-25-03

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INTEGRITY IN TESTING

TENSILE STRENGTH TEST RESULTS

ASTM D-6637

CLIENT: NORTH DAKOTA D.O.T.
CLIENT PROJECT: AC-HPP-4-052(044)058
PROJECT NO.: L03127-13
LAB IDNO.: L03127-13-01
MATERIAL: TENSAR BX1100 GEOGRID
SAMPLE: # 5
LOT NO.: 013

TEST	UNITS	SPECIMEN NO. 1	2	3	4	5	AVG	STD
RIB COUNT	MD Ribs/ft	7.95						
	CD Ribs/ft	10.63						
WIDE WIDTH STRENGTH MD	2%-MD lbs/ft	406	427	431	423	418	**421**	9.86
	5%-MD lbs/ft	731	761	771	772	764	**760**	16.87
	Ult.-MD lbs/ft	883	914	915	977	957	**929**	37.64
	Elong at Peak-%	7	8	7	8	8	**8**	0.57
WIDE WIDTH STRENGTH CD	2%-CD lbs/ft	674	664	659	574	683	**651**	43.98
	5%-CD lbs/ft	1,261	1,246	1,251	1,204	1,266	**1,246**	24.57
	Ult.-CD lbs/ft	1,538	1,559	1,610	1,612	1,508	**1,565**	45.51
	Elong at Peak-%	8	8	9	10	7	**9**	1.26

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